

ANNEX D

Methodology for Estimating Emissions of CH₄, N₂O, and Criteria Pollutants from Mobile Combustion

Estimates of CH₄ and N₂O Emissions

Greenhouse gas emissions from mobile combustion are reported by transport mode (e.g., road, rail, air, and water), vehicle type, and fuel type. The EPA does not systematically track emissions of CH₄ and N₂O as in EPA (2000b); therefore, estimates of these gases were developed using a methodology similar to that outlined in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997).

Step 1: Determine Vehicle Miles Traveled or Fuel Consumption by Vehicle Type, Fuel Type, and Model Year

Activity data were obtained from a number of U.S. government agency publications. Depending on the category, these basic activity data included such information as fuel consumption, fuel deliveries, and vehicle miles traveled (VMT). The activity data for highway vehicles included estimates of VMT by vehicle type from the Federal Highway Administration's (FHWA) Highway Performance Monitoring System database, as noted in EPA (2000b).

National VMT data for gasoline and diesel highway vehicles are presented in Table D-1 and Table D-2 respectively. Total VMT for each highway category (i.e., gasoline passenger cars, light-duty gasoline trucks, heavy-duty gasoline vehicles, diesel passenger cars, light-duty diesel trucks, heavy-duty diesel vehicles, and motorcycles) were distributed across 25 model years based on the VMT distribution by vehicle age shown in Table D-5. This distribution was derived by weighting the temporally fixed age distribution of the U.S. vehicle fleet according to vehicle registrations (Table D-3) by the average annual age-specific vehicle mileage accumulation of U.S. vehicles (Table D-4), which were both obtained from EPA's Mobile6 model (EPA 2000a).

Activity data for gasoline passenger cars and light-duty trucks in California were developed separately due to the different emission control technologies deployed in that state relative to the rest of the country. Unlike the rest of the United States, beginning in model year 1994, a fraction of the computed California VMT for gasoline passenger cars and light-duty trucks was attributed to low emission vehicles (LEVs). LEVs have not yet been widely deployed in other states. Based upon U.S. Department of Transportation statistics for 1994, it was assumed that 8.7 percent of national VMT occurred in California, and this value was used for the entire time series.

Activity data for non-highway vehicles were based on annual fuel consumption statistics by transportation mode and fuel type. Consumption data for distillate and residual fuel oil by ships and boats (i.e., vessel bunkering), construction equipment, farm equipment, and locomotives were obtained from EIA (2000b). In the case of ships and boats, the EIA (2000b) vessel bunkering data was reduced by the amount of fuel used for international bunkers.¹ Data on the consumption of jet fuel in aircraft were obtained directly from DOT/BTS, as described under CO₂ from Fossil Fuel Combustion, and were reduced by the amount allocated to international bunker fuels. Data on aviation gasoline consumed in aircraft were taken from FAA (2000). Data on the consumption of motor gasoline by ships and boats, construction equipment, farm equipment, and locomotives data were drawn from FHWA (1999). For these vehicles, 1998 fuel consumption data were used as a proxy because 1999 data were unavailable. The activity data used for non-highway vehicles are included in Table D-6.

Step 2: Allocate VMT Data to Control Technology Type for Highway Vehicles

For highway sources, VMT by vehicle type for each model year were distributed across various control technologies as shown in Table D-7, Table D-8, Table D-9, Table D-10, and Table D-11. Again, California gasoline-fueled passenger cars and light-duty trucks were treated separately due to that state's distinct vehicle

¹ See International Bunker Fuels section of the Energy Chapter.

emission standards—including the introduction of Low Emission Vehicles (LEVs) in 1994—compared with the rest of the United States. The categories “Tier 0” and “Tier 1” were substituted for the early three-way catalyst and advanced three-way catalyst categories, respectively, as defined in the *Revised 1996 IPCC Guidelines*. Tier 0, Tier 1, and LEV are actually U.S. emission regulations, rather than control technologies; however, each does correspond to particular combinations of control technologies and engine design. Tier 1 and its predecessor Tier 0 both apply to vehicles equipped with three-way catalysts. The introduction of “early three-way catalysts,” and “advance three-way catalysts” as described in the *Revised 1996 IPCC Guidelines*, roughly correspond to the introduction of Tier 0 and Tier 1 regulations (EPA 1998).

Step 3: Determine the Amount of CH₄ and N₂O Emitted by Vehicle, Fuel, and Control Technology Type

Emissions of CH₄ and N₂O from highway vehicles were calculated by multiplying emission factors in IPCC/UNEP/OECD/IEA (1997) by the VMT for each highway category each year as described in Step 1 (see Table D-12). The emission factors for highway sources were derived from the EPA’s MOBILE5a mobile source emissions model (EPA 1997). The MOBILE5a model uses information on ambient temperature, diurnal temperature range, altitude, vehicle speeds, national vehicle registration distributions, gasoline volatility, emission control technologies, fuel composition, and the presence or absence of vehicle inspection/maintenance programs in order to produce these factors. Emissions of CH₄ and N₂O from non-highway vehicles were calculated by multiplying emission factors in IPCC/UNEP/OECD/IEA (1997) by activity data for each vehicle type as described in Step 1 (see and Table D-13).

Emissions of N₂O—in contrast to CH₄, CO, NO_x, and NMVOCs—have not been extensively studied and are currently not well characterized. The limited number of studies that have been performed on highway vehicle emissions of N₂O have shown that emissions are generally greater from vehicles with catalytic converter systems than those without such controls, and greater from aged than from new catalysts. These systems control tailpipe emissions of NO_x (i.e., NO and NO₂) by catalytically reducing NO_x to N₂. Suboptimal catalyst performance, caused by as yet poorly understood factors, results in incomplete reduction and the conversion of some NO_x to N₂O rather than to N₂. Fortunately, newer vehicles with catalyst and engine designs meeting the more recent Tier 1 and LEV standards have shown reduced emission rates of both NO_x and N₂O compared with earlier catalyst designs.

In order to better characterize the process by which N₂O is formed by catalytic controls and to develop a more accurate national emission estimate, the EPA’s Office of Transportation and Air Quality—at its National Vehicle and Fuel Emissions Laboratory (NVFEL)—conducted a series of tests in order to measure emission rates of N₂O from used Tier 1 and LEV gasoline-fueled passenger cars and light-duty trucks equipped with catalytic converters. These tests and a review of the literature were used to develop the emission factors for N₂O (EPA 1998). The following references were used in developing the N₂O emission factors for gasoline-fueled highway passenger cars presented in Table D-12:

- *LEVs*. Tests performed at NVFEL (EPA 1998)²
- *Tier 1*. Tests performed at NVFEL (EPA 1998)
- *Tier 0*. Smith and Carey (1982), Barton and Simpson (1994), and one car tested at NVFEL (EPA 1998)
- *Oxidation Catalyst*. Smith and Carey (1982), Urban and Garbe (1979)
- *Non-Catalyst*. Prigent and de Soete (1989), Dasch (1992), and Urban and Garbe (1979)

Nitrous oxide emission factors for other types of gasoline-fueled vehicles—light-duty trucks, heavy-duty vehicles, and motorcycles—were estimated by adjusting the factors for gasoline passenger cars, as described above, by their relative fuel economies. This adjustment was performed using the carbon dioxide emission rates in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997) as a proxy for fuel economy (see Table D-12). Data from the literature and tests performed at NVFEL support the conclusion that light-duty trucks have higher emission rates than passenger cars. However, the use of fuel-consumption ratios to determine emission factors is considered a temporary measure only, to be replaced as soon as real data are available.

² It was assumed that LEVs would be operated using low-sulfur fuel (i.e., Indolene at 24 ppm sulfur). All other NVFEL tests were performed using a standard commercial fuel (CAAB at 285 ppm sulfur). Emission tests by NVFEL have consistently exhibited higher N₂O emission rates from higher sulfur fuels on Tier 1 and LEV vehicles.

The resulting N₂O emission factors employed for gasoline highway vehicles are lower than the U.S. default values presented in the *Revised 1996 IPCC Guidelines*, but are higher than the European default values, both of which were published before the more recent tests and literature review conducted by the NVFEL. The U.S. defaults in the *Guidelines* were based on three studies that tested a total of five cars using European rather than U.S. test procedures.

Nitrous oxide emission factors for diesel highway vehicles were taken from the European default values found in the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997). There is little data addressing N₂O emissions from U.S. diesel-fueled vehicles, and in general, European countries have had more experience with diesel-fueled vehicles. U.S. default values in the *Revised 1996 IPCC Guidelines* were used for non-highway vehicles.

Compared to regulated tailpipe emissions, there is relatively little data available to estimate emission factors for N₂O. Nitrous oxide is not a regulated criteria pollutant, and measurements of it in automobile exhaust have not been routinely collected. Further testing is needed to reduce the uncertainty in nitrous oxide emission factors for all classes of vehicles, using realistic driving regimes, environmental conditions, and fuels.

Estimates of NO_x, CO, and NMVOC Emissions

The emission estimates of NO_x, CO, and NMVOCs for mobile combustion were taken directly from the EPA's *National Air Pollutant Emissions Trends, 1900 - 1999* (EPA 2000b). This EPA report provides emission estimates for these gases by sector and fuel type using a "top down" estimating procedure whereby emissions were calculated using basic activity data, such as amount of fuel delivered or miles traveled, as indicators of emissions.

Table D-14 through Table D-16 provide complete emissions estimates for 1990 through 1999.

Table D-1: Vehicle Miles Traveled for Gasoline Highway Vehicles (10⁹ Miles)

Year	Passenger Cars ^a	Light-Duty Trucks ^a	Heavy-Duty Vehicles	Motorcycles	Passenger Cars (CA) ^b	Light-Duty Trucks (CA) ^b
1990	1,268.2	520.3	42.1	9.6	120.8	49.6
1991	1,223.0	588.0	42.9	9.3	116.5	56.0
1992	1,235.4	640.1	43.7	9.4	117.7	61.0
1993	1,238.5	675.3	46.0	9.4	118.0	64.3
1994	1,266.9	692.4	49.6	9.6	120.7	66.0
1995	1,295.3	715.4	50.8	9.8	123.4	68.2
1996	1,328.8	660.9	82.4	9.9	126.6	63.0
1997	1,367.8	696.3	82.7	10.1	130.3	66.3
1998	1,407.4	711.6	80.7	10.3	134.1	67.8
1999	1,434.9	725.5	82.3	10.5	136.7	69.1

^a Excludes California

^b California VMT for passenger cars and light-duty trucks was treated separately and estimated as 8.7 percent of national total. Source: VMT data are the same as those used in EPA (2000b).

Table D-2: Vehicle Miles Traveled for Diesel Highway Vehicles (10⁹ Miles)

Year	Passenger Cars	Light-Duty Trucks	Heavy-Duty Vehicles
1990	19.2	4.7	109.9
1991	18.5	5.3	112.4
1992	18.7	5.8	115.5
1993	18.7	6.1	120.0
1994	19.1	6.3	127.0
1995	19.6	6.5	133.8
1996	8.1	4.4	191.0
1997	6.6	3.9	201.2
1998	5.3	3.6	206.2
1999	5.4	3.6	210.5

Source: VMT data are the same as those used in EPA (2000b).

Table D-3: Age Distribution by Vehicle/Fuel Type for Highway Vehicles

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
1	5.3%	5.8%	4.9%	5.3%	5.9%	4.2%	14.4%
2	7.1%	7.6%	8.9%	7.1%	7.4%	7.8%	16.8%
3	7.1%	7.5%	8.1%	7.1%	6.9%	7.2%	13.5%
4	7.1%	7.3%	7.4%	7.1%	6.4%	6.7%	10.9%
5	7.0%	7.1%	6.8%	7.0%	6.0%	6.2%	8.8%
6	7.0%	6.8%	6.2%	7.0%	5.6%	5.8%	7.0%
7	6.9%	6.5%	5.6%	6.9%	5.2%	5.3%	5.6%
8	6.8%	6.1%	5.1%	6.8%	4.8%	5.0%	4.5%
9	6.6%	5.7%	4.7%	6.6%	4.5%	4.6%	3.6%
10	6.3%	5.2%	4.3%	6.3%	4.2%	4.3%	2.9%
11	5.9%	4.7%	3.9%	5.9%	3.9%	4.0%	2.3%
12	5.4%	4.2%	3.6%	5.4%	3.6%	3.7%	9.7%
13	4.6%	3.6%	3.3%	4.6%	3.4%	3.4%	0.0%
14	3.6%	3.1%	3.0%	3.6%	3.2%	3.2%	0.0%
15	2.9%	2.6%	2.7%	2.9%	2.9%	2.9%	0.0%
16	2.3%	2.2%	2.5%	2.3%	2.7%	2.7%	0.0%
17	1.8%	1.8%	2.3%	1.8%	2.5%	2.5%	0.0%
18	1.4%	1.4%	2.1%	1.4%	2.4%	2.4%	0.0%
19	1.1%	1.2%	1.9%	1.1%	2.2%	2.2%	0.0%
20	0.9%	1.1%	1.7%	0.9%	2.1%	2.0%	0.0%
21	0.7%	1.1%	1.6%	0.7%	1.9%	1.9%	0.0%
22	0.6%	1.0%	1.5%	0.6%	1.8%	1.8%	0.0%
23	0.4%	1.0%	1.3%	0.4%	1.7%	1.6%	0.0%
24	0.4%	0.9%	1.2%	0.4%	1.6%	1.5%	0.0%
25	1.0%	4.6%	5.4%	1.0%	7.3%	7.2%	0.0%

LDGV (gasoline passenger cars, also referred to as light-duty gas vehicles)

LDGT (light-duty gas trucks)

HDGV (heavy-duty gas vehicles)

LDDV (diesel passenger cars, also referred to as light-duty diesel vehicles)

LDDT (light-duty diesel trucks)

HDDV (heavy-duty diesel vehicles)

MC (motorcycles)

Note: Based on vehicle registrations.

Table D-4: Annual Age-specific Vehicle Mileage Accumulation of U.S. Vehicles (Miles)

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
1	14,910	19,906	20,218	14,910	26,371	28,787	4,786
2	14,174	18,707	18,935	14,174	24,137	26,304	4,475
3	13,475	17,559	17,100	13,475	22,095	24,038	4,164
4	12,810	16,462	16,611	12,810	20,228	21,968	3,853
5	12,178	15,413	15,560	12,178	18,521	20,078	3,543
6	11,577	14,411	14,576	11,577	16,960	18,351	3,232
7	11,006	13,454	13,655	11,006	15,533	16,775	2,921
8	10,463	12,541	12,793	10,463	14,227	15,334	2,611
9	9,947	11,671	11,987	9,947	13,032	14,019	2,300
10	9,456	10,843	11,231	9,456	11,939	12,817	1,989
11	8,989	10,055	10,524	8,989	10,939	11,719	1,678
12	8,546	9,306	9,863	8,546	10,024	10,716	1,368
13	8,124	8,597	9,243	8,124	9,186	9,799	1,368
14	7,723	7,925	8,662	7,723	8,420	8,962	1,368
15	7,342	7,290	8,028	7,342	7,718	8,196	1,368
16	6,980	6,690	7,610	6,980	7,075	7,497	1,368
17	6,636	6,127	7,133	6,636	6,487	6,857	1,368
18	6,308	5,598	6,687	6,308	5,948	6,273	1,368
19	5,997	5,103	6,269	5,997	5,454	5,739	1,368
20	5,701	4,642	5,877	5,701	5,002	5,250	1,368
21	5,420	4,214	5,510	5,420	4,588	4,804	1,368
22	5,152	3,818	5,166	5,152	4,209	4,396	1,368
23	4,898	3,455	4,844	4,898	3,861	4,023	1,368
24	4,656	3,123	4,542	4,656	3,542	3,681	1,368
25	4,427	2,822	4,259	4,427	3,250	3,369	1,368

Table D-5: VMT Distribution by Vehicle Age and Vehicle/Fuel Type

Vehicle Age	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
1	7.51%	9.41%	7.89%	7.51%	11.50%	8.27%	19.39%
2	9.52%	11.56%	13.48%	9.52%	13.07%	14.00%	21.15%
3	9.05%	10.62%	11.11%	9.05%	11.15%	11.86%	15.82%
4	8.59%	9.70%	9.85%	8.59%	9.51%	10.05%	11.82%
5	8.14%	8.80%	8.43%	8.14%	8.11%	8.52%	8.77%
6	7.68%	7.92%	7.21%	7.68%	6.92%	7.22%	6.37%
7	7.22%	7.04%	6.16%	7.22%	5.90%	6.13%	4.60%
8	6.72%	6.19%	5.27%	6.72%	5.04%	5.20%	3.31%
9	6.20%	5.36%	4.51%	6.20%	4.30%	4.41%	2.33%
10	5.64%	4.57%	3.86%	5.64%	3.67%	3.74%	1.62%
11	5.03%	3.82%	3.31%	5.03%	3.13%	3.18%	1.09%
12	4.38%	3.14%	2.83%	4.38%	2.67%	2.70%	3.73%
13	3.54%	2.52%	2.42%	3.54%	2.28%	2.29%	0.00%
14	2.67%	1.99%	2.07%	2.67%	1.95%	1.94%	0.00%
15	2.01%	1.54%	1.76%	2.01%	1.66%	1.65%	0.00%
16	1.52%	1.16%	1.52%	1.52%	1.42%	1.40%	0.00%
17	1.14%	0.87%	1.30%	1.14%	1.21%	1.19%	0.00%
18	0.86%	0.64%	1.12%	0.86%	1.04%	1.01%	0.00%
19	0.65%	0.50%	0.96%	0.65%	0.89%	0.86%	0.00%
20	0.49%	0.43%	0.82%	0.49%	0.76%	0.73%	0.00%
21	0.37%	0.37%	0.70%	0.37%	0.65%	0.62%	0.00%
22	0.28%	0.32%	0.60%	0.28%	0.55%	0.53%	0.00%
23	0.21%	0.27%	0.52%	0.21%	0.47%	0.45%	0.00%
24	0.16%	0.23%	0.44%	0.16%	0.40%	0.38%	0.00%
25	0.43%	1.04%	1.85%	0.43%	1.75%	1.65%	0.00%

Note: Estimated by weighting data in Table D-3 by data in Table D-4.

Table D-6: Fuel Consumption for Non-Highway Vehicles by Fuel Type (U.S. Gallons)

Vehicle Type/Year	Residual	Diesel	Jet Fuel	Other
Aircraft^a				
1990	-	-	18,265,975,286	374,216,115
1991	-	-	17,496,936,548	347,126,395
1992	-	-	17,269,984,984	341,582,453
1993	-	-	17,414,327,932	319,448,684
1994	-	-	18,269,315,288	317,306,704
1995	-	-	17,809,152,465	329,318,581
1996	-	-	18,749,831,246	310,796,773
1997	-	-	18,603,782,852	330,284,570
1998	-	-	19,060,116,911	295,344,794
1999	-	-	19,206,444,324	325,912,623
Ships and Boats^b				
1990	1,521,437,386	1,697,600,270	-	1,300,400,000
1991	1,486,167,178	1,693,361,391	-	1,709,700,000
1992	2,347,064,583	1,706,143,771	-	1,316,170,000
1993	2,758,924,466	1,546,310,902	-	873,687,000
1994	2,499,868,472	1,630,092,618	-	896,700,000
1995	2,994,692,916	1,518,608,116	-	1,060,394,000
1996	2,286,349,693	1,839,335,006	-	993,671,000
1997	1,011,486,526	1,801,798,270	-	987,193,000
1998	730,817,822	1,613,162,288	-	956,232,000
1999	2,391,245,568	1,871,478,578	-	956,232,001
Construction Equipment^c				
1990	-	2,508,300,000	-	1,523,600,000
1991	-	2,447,400,000	-	1,384,900,000
1992	-	2,287,642,000	-	1,492,200,000
1993	-	2,323,183,000	-	1,270,386,667
1994	-	2,437,142,000	-	1,312,161,667
1995	-	2,273,162,000	-	1,351,642,667
1996	-	2,386,973,000	-	1,365,550,667
1997	-	2,385,236,000	-	1,397,748,667
1998	-	2,432,182,000	-	1,373,933,667
1999	-	2,409,231,000	-	1,199,593,667
Farm Equipment^b				
1990	-	3,164,200,000	-	812,800,000
1991	-	3,144,200,000	-	776,200,000
1992	-	3,274,811,000	-	805,500,000
1993	-	3,077,122,000	-	845,320,000
1994	-	3,062,436,000	-	911,996,000
1995	-	3,093,224,000	-	926,732,000
1996	-	3,225,029,000	-	918,085,000
1997	-	3,206,359,000	-	984,450,000
1998	-	2,965,006,000	-	906,941,000
1999	-	2,805,157,000	-	702,700,000
Locomotives				
1990	25,422	3,210,111,000	-	-
1991	6,845	3,026,292,000	-	-
1992	8,343	3,217,231,000	-	-
1993	4,065	2,906,998,000	-	-
1994	5,956	3,063,441,000	-	-
1995	6,498	3,191,023,000	-	-
1996	9,309	3,266,861,000	-	-
1997	3,431	3,067,400,000	-	-
1998	2,587	2,833,276,000	-	-
1999	3,540	2,789,926,000	-	-

- Not applicable

^a Other fuel is aviation gasoline.^b Other fuel is motor gasoline.^c Construction Equipment includes snowmobiles. Other fuel is motor gasoline.

Table D-7: Control Technology Assignments for Gasoline Passenger Cars (Percent of VMT)*

Model Years	Non-catalyst	Oxidation	Tier 0	Tier 1
1973-1974	100%	-	-	-
1975	20%	80%	-	-
1976-1977	15%	85%	-	-
1978-1979	10%	90%	-	-
1980	5%	88%	7%	-
1981	-	15%	85%	-
1982	-	14%	86%	-
1983	-	12%	88%	-
1984-1993	-	-	100%	-
1994	-	-	60%	40%
1995	-	-	20%	80%
1996-1999	-	-	-	100%

* Excluding California VMT

- Not applicable

Table D-8: Control Technology Assignments for Gasoline Light-Duty Trucks (Percent of VMT)*

Model Years	Non-catalyst	Oxidation	Tier 0	Tier 1
1973-1974	100%	-	-	-
1975	30%	70%	-	-
1976	20%	80%	-	-
1977-1978	25%	75%	-	-
1979-1980	20%	80%	-	-
1981	-	95%	5%	-
1982	-	90%	10%	-
1983	-	80%	20%	-
1984	-	70%	30%	-
1985	-	60%	40%	-
1986	-	50%	50%	-
1987-1993	-	5%	95%	-
1994	-	-	60%	40%
1995	-	-	20%	80%
1996-1999	-	-	-	100%

* Excluding California VMT

- Not applicable

Table D-9: Control Technology Assignments for California Gasoline Passenger Cars and Light-Duty Trucks (Percent of VMT)

Model Years	Non-catalyst	Oxidation	Tier 0	Tier 1	LEV
1973-1974	100%	-	-	-	-
1975-1979	-	100%	-	-	-
1980-1981	-	15%	85%	-	-
1982	-	14%	86%	-	-
1983	-	12%	88%	-	-
1984-1991	-	-	100%	-	-
1992	-	-	60%	40%	-
1993	-	-	20%	80%	-
1994	-	-	-	90%	10%
1995	-	-	-	85%	15%
1996-1999	-	-	-	80%	20%

* Excluding California VMT

- Not applicable

Table D-10: Control Technology Assignments for Gasoline Heavy-Duty Vehicles (Percent of VMT)

Model Years	Uncontrolled	Non-catalyst	Oxidation	Tier 0
≤1981	100%	-	-	-
1982-1984	95%	-	5%	-
1985-1986	-	95%	5%	-
1987	-	70%	15%	15%
1988-1989	-	60%	25%	15%
1990-1999	-	45%	30%	25%

* Excluding California VMT

- Not applicable

Table D-11: Control Technology Assignments for Diesel Highway VMT

Vehicle Type/Control Technology	Model Years
Diesel Passenger Cars and Light-Duty Trucks	
Uncontrolled	1966-1982
Moderate control	1983-1995
Advanced control	1996-1999
Heavy-Duty Diesel Vehicles	
Uncontrolled	1966-1972
Moderate control	1983-1995
Advanced control	1996-1999
Motorcycles	
Uncontrolled	1966-1995
Non-catalyst controls	1996-1999

Table D-12: Emission Factors (g/km) for CH₄ and N₂O and “Fuel Economy” (g CO₂/km)^c for Highway Mobile Combustion

Vehicle Type/Control Technology	N ₂ O	CH ₄	g CO ₂ /km
Gasoline Passenger Cars			
Low Emission Vehicles ^a	0.0176	0.025	280
Tier 1	0.0288	0.030	285
Tier 0	0.0507	0.040	298
Oxidation Catalyst	0.0322	0.070	383
Non-Catalyst	0.0103	0.120	531
Uncontrolled	0.0103	0.135	506
Gasoline Light-Duty Trucks			
Low Emission Vehicles ^a	0.0249	0.030	396
Tier 1	0.0400	0.035	396
Tier 0	0.0846	0.070	498
Oxidation Catalyst	0.0418	0.090	498
Non-Catalyst	0.0117	0.140	601
Uncontrolled	0.0118	0.135	579
Gasoline Heavy-Duty Vehicles			
Tier 0	0.1729	0.075	1,017
Oxidation Catalyst ^b	0.0870	0.090	1,036
Non-Catalyst Control	0.0256	0.125	1,320
Uncontrolled	0.0269	0.270	1,320
Diesel Passenger Cars			
Advanced	0.0100	0.01	237
Moderate	0.0100	0.01	248
Uncontrolled	0.0100	0.01	319
Diesel Light Trucks			
Advanced	0.0200	0.01	330
Moderate	0.0200	0.01	331
Uncontrolled	0.0200	0.01	415
Diesel Heavy-Duty Vehicles			
Advanced	0.0300	0.04	987
Moderate	0.0300	0.05	1,011
Uncontrolled	0.0300	0.06	1,097
Motorcycles			
Non-Catalyst Control	0.0042	0.13	219
Uncontrolled	0.0054	0.26	266

^a Applied to California VMT only.

^b Methane emission factor assumed based on light-duty trucks oxidation catalyst value.

^c The carbon emission factor (g CO₂/km) was used as a proxy for fuel economy because of the greater number of significant figures compared to the km/L values presented in (IPCC/UNEP/OECD/IEA 1997).

Table D-13: Emission Factors for CH₄ and N₂O Emissions from Non-Highway Mobile Combustion (g/kg Fuel)

Vehicle Type/Fuel Type	N ₂ O	CH ₄
Ships and Boats		
Residual	0.08	0.23
Distillate	0.08	0.23
Gasoline	0.08	0.23
Locomotives		
Residual	0.08	0.25
Diesel	0.08	0.25
Coal	0.08	0.25
Farm Equipment		
Gas/Tractor	0.08	0.45
Other Gas	0.08	0.45
Diesel/Tractor	0.08	0.45
Other Diesel	0.08	0.45
Construction		
Gas Construction	0.08	0.18
Diesel Construction	0.08	0.18
Other Non-Highway		
Gas Snowmobile	0.08	0.18
Gas Small Utility	0.08	0.18
Gas HD Utility	0.08	0.18
Diesel HD Utility	0.08	0.18
Aircraft		
Jet Fuel	0.1	0.087
Aviation Gasoline	0.04	2.64

Table D-14: NO_x Emissions from Mobile Combustion, 1990-1999 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gasoline Highway	4,418	4,744	4,909	5,047	5,156	4,867	4,747	4,756	4,629	4,496
Passenger Cars	2,723	2,774	2,800	2,817	2,867	2,750	2,716	2,706	2,649	2,582
Light-Duty Trucks	1,408	1,669	1,818	1,933	1,959	1,807	1,550	1,580	1,545	1,486
Heavy-Duty Vehicles	277	291	281	286	318	300	470	458	424	416
Motorcycles	10	10	11	11	11	11	11	11	11	12
Diesel Highway	2,123	2,112	2,129	2,174	2,261	2,351	3,230	3,338	3,368	3,297
Passenger Cars	26	30	30	30	31	31	13	10	8	7
Light-Duty Trucks	57	10	10	11	11	11	7	6	5	5
Heavy-Duty Vehicles	2,040	2,072	2,089	2,133	2,219	2,308	3,210	3,322	3,355	3,284
Non-Highway	4,358	4,445	4,476	4,483	4,550	4,653	4,916	5,001	5,024	5,001
Ships and Boats	908	955	926	886	898	905	939	953	964	975
Locomotives	843	842	858	857	859	898	1,073	1,109	1,102	1,092
Farm Equipment	819	837	854	870	886	901	852	851	844	826
Construction Equipment	1,003	1,020	1,036	1,052	1,069	1,090	1,153	1,159	1,155	1,137
Aircraft ^a	143	141	142	142	146	150	152	152	158	159
Other ^b	642	650	661	676	692	709	748	777	801	813
Total	10,900	11,301	11,515	11,705	11,967	11,870	12,893	13,095	13,021	12,794

^a Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

^b "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

Table D-15: CO Emissions from Mobile Combustion, 1990-1999 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gasoline Highway	51,840	55,949	54,326	54,852	55,750	48,375	47,443	46,392	45,496	43,327
Passenger Cars	31,576	32,208	30,466	29,933	30,048	26,854	26,285	25,809	25,606	24,664
Light-Duty Trucks	15,530	18,709	19,538	20,679	20,515	17,630	15,307	15,376	15,375	14,620
Heavy-Duty Vehicles	4,562	4,871	4,160	4,067	5,011	3,722	5,679	5,034	4,338	3,866
Motorcycles	172	161	162	172	176	169	171	173	177	177
Diesel Highway	1,180	1,204	1,227	1,243	1,315	1,349	1,899	1,976	2,005	2,023
Passenger Cars	20	24	24	25	26	27	11	9	7	7
Light-Duty Trucks	42	8	8	9	9	9	6	5	5	5
Heavy-Duty Vehicles	1,119	1,172	1,195	1,209	1,280	1,313	1,882	1,961	1,993	2,011
Non-Highway	16,503	16,860	17,236	17,592	17,959	18,348	23,048	22,857	22,787	22,829
Ships and Boats	2,041	2,053	2,054	2,053	2,060	2,065	2,132	2,150	2,166	2,170
Locomotives	110	109	113	108	104	103	106	110	109	108
Farm Equipment	527	537	547	557	566	575	458	459	460	458
Construction Equipment	1,148	1,171	1,194	1,216	1,238	1,258	1,452	1,413	1,379	1,333
Aircraft ^a	820	806	818	821	830	855	861	869	903	909
Other ^b	11,857	12,184	12,511	12,837	13,162	13,492	18,039	17,856	17,770	17,851
Total	69,523	74,012	72,789	73,687	75,024	68,072	72,390	71,225	70,288	68,179

^a Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

^b "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

Table D-16: NMVOCs Emissions from Mobile Combustion, 1990-1999 (Gg)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gasoline Highway	5,545	5,753	5,416	5,470	5,654	4,980	4,704	4,632	4,647	4,544
Passenger Cars	3,298	3,240	2,953	2,901	2,989	2,714	2,608	2,578	2,626	2,604
Light-Duty Trucks	1,829	2,103	2,129	2,241	2,257	1,937	1,621	1,623	1,622	1,562
Heavy-Duty Vehicles	368	378	304	296	375	295	442	398	363	340
Motorcycles	51	33	30	31	33	34	33	33	35	38
Diesel Highway	300	288	289	289	300	296	323	301	287	263
Passenger Cars	8	10	10	10	11	11	4	4	3	3
Light-Duty Trucks	21	4	4	5	5	5	3	3	2	2
Heavy-Duty Vehicles	270	275	274	274	284	280	316	295	282	258
Non-Highway	2,309	2,341	2,353	2,381	2,424	2,449	3,224	3,090	2,994	2,929
Ships and Boats	743	748	729	731	747	738	865	872	878	874
Locomotives	48	47	49	47	45	45	44	45	45	44
Farm Equipment	133	133	132	132	131	130	112	110	106	99
Construction Equipment	204	208	212	216	220	225	249	240	229	214
Aircraft ^a	163	161	162	160	159	161	161	161	166	166
Other ^b	1,018	1,045	1,068	1,095	1,122	1,150	1,793	1,662	1,569	1,532
Total	8,154	8,383	8,058	8,140	8,378	7,725	8,251	8,023	7,928	7,736

^a Aircraft estimates include only emissions related to LTO cycles, and therefore do not include cruise altitude emissions.

^b "Other" includes gasoline powered recreational, industrial, lawn and garden, light commercial, logging, airport service, other equipment; and diesel powered recreational, industrial, lawn and garden, light construction, airport service.

Note: Totals may not sum due to independent rounding.

